Moody Tower Measurements – Overview

Bernhard Rappenglueck, Barry Lefer (UH)

What are the main sources and sinks for radicals in the urban air of Houston?
What processes determine the radical budget in the urban air of Houston?
What are the impacts with regard to the formation of secondary species?
What are the anthropogenic vs biogenic contributions to photochemical processes in Houston?

Moody Tower Measurements – Overview

Rappenglueck (PI), Lefer (Co-PI)  Main Funding: HARC

Measurement Site

• UH - Moody Tower

Research Issues
Photochemical Processes

Termination by NO\(_x\)

Photolysis of O\(_3\), RCHO, HONO

Termination by RO\(_x\) + RO\(_x\)

PAN’s

PAN (anthropogenic)
MPAN (biogenic)

HNO\(_3\)

NO\(_2\)

O\(_3\)

O(\(^1\)D)

OH\(^*\)

RC\(_3\)

CO

RCHO

H\(_2\)O

H\(_2\)O

RC(O)O\(^*\)

RCH\(_2\)O\(^*\)

+O\(_2\)

RC(O)O\(_2\)\(^*\)

RCH\(_2\)O\(_2\)\(^*\)

HO\(_2\)\(^*\)

RCHO

RCO\(^*\)

H\(^*\)

RCH\(^*\)

+O\(_2\)

H\(_2\)O

CO\(_2\)

PAN’s

PPN (anthropogenic)
MPAN (biogenic)

....
Nighttime Chemical Processes

- O₃
- NO₂ → NO₃
- NO₂ → NO
- NO → RO₂
- RO₂ → HO₂
- HO₂ → OH
- HNO₃(s)
- N₂O₅
- NO → NO₂
- NO₂ → N₂O₅
- VOCs
- O₃
- NO₂
- H₂O
- NO

Chemical processes involve
- O₃
- NO₂
- NO₃
- NO
- RO₂
- HO₂
- OH
- HNO₃(s)

Nighttime reactions include
- O₃ → NO₂
- NO₂ → NO₃
- NO₃ → NO₂
- NO₂ → NO
- NO → RO₂
- RO₂ → HO₂
- HO₂ → OH
<table>
<thead>
<tr>
<th>Moody Tower – Measurements: Pis - Organizations</th>
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<tbody>
<tr>
<td>- Meteorological parameters (B. Lefer &amp; B. Rappenglueck, UH)</td>
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<td>- O$_3$, CO, NO, NO$_2$, NO$_x$ (B. Lefer &amp; B. Rappenglueck, UH)</td>
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<td>- PAN, PPN, MPAN, online VOC, offline VOC, HCHO, H$_2$O$_2$ (B. Rappenglueck, UH)</td>
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<td>- photolysis of O$_3$, NO$_2$, HONO, HCHO and 16 other important photolysis reactions, UV/VIS AODs, O$_3$ Column, Cloud Camera (B. Lefer, UH)</td>
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<td>- CO, NO$_Y$, SO$_2$ (W. Luke, NOAA)</td>
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<td>- DOAS: O$_3$, NO$_2$, NO$_3$, N$_2$O$_5$, HONO, HCHO; Maxdoas: NO$_2$, HCHO (J. Stutz, UCLA)</td>
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<td>- OH, HO$_2$, RO$_2$, OH reactivity, O$_3$, NO, NO$_x$ (W. Brune, PSU)</td>
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<td>- Oxy-VOCs, HNO$_3$ (R. Zhang, TAMU)</td>
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<td>- HCHO, C$_2$H$_4$ (M. Fraser, U Rice)</td>
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<td>- Aerosol composition, EC/OC (R. Griffin, UNH)</td>
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<td>- Water soluble organic carbon gases and aerosols, HNO$_3$, HONO (J. Dibb, UNH)</td>
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<td>- PM2.5: Mass, EC/OC, Water soluble organic carbon (R. Weber, GATECH)</td>
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<td>- elemental, particle bond and reactive gaseous Hg (S. Brooks, NOAA)</td>
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<td>- Cloud Condensation Nuclei (P. Chuang, UC-Santa Cruz)</td>
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<td>- Aerosol Scattering and Extinction (D. Atkinson, Portland State)</td>
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<td>- Aerosol size distribution (D. Collins, S. Brooks, TAMU)</td>
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<td>- Aerosol backscatter remote sensing (C. Flynn, PNNL)</td>
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Moody Tower:
Site Properties

- 60 m a.g.l.
- south of downtown Houston
Moody Tower: Overhead View UH Campus
Moody Tower: Overhead View Downtown
Moody Tower:
View NNE
Moody Tower: View West

Medical Center

Galleria
Moody Tower: View S

South Moody Tower
Moody Tower: View SE

View to the Galveston....
Moody Tower:
Site Properties

- 60 m a.g.l.
- south of downtown Houston
- representative

in-situ (green lines; UH)
vs
DOAS measurements (UCLA)
Moody Tower: Site Properties

- 60 m a.g.l.
- south of downtown Houston
- representative

in-situ (green lines; UH) vs DOAS measurements (UCLA)

Daytime: generally good agreement.
Nighttime: At night Moody tower in-situ observations often fall between the lower and middle light-path DOAS mixing ratios.
Large variability:
- low background values (30 ppb): air masses from SE (Gulf of Mexico)
- high background values (up to 80 ppb): continental air masses
- Very high values (160 ppb): Ship Channel
Background PAN vs high PAN plumes

PI: B. Rappenglueck (UH)

Large variability:
- low background values (<30 ppt): air masses from SE (Gulf of Mexico)
- high values (4.2 ppb): Ship Channel
Wind Direction

Pts:
B. Lefer
B. Rappenglueck
(UH)

9:00 am – 9:00 pm (LT)

9:00 pm – 9:00 am (LT)
Wind Direction

Daytime and nighttime: S/SW wind directions present

9:00 am – 9:00 pm (LT)

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Pts:
B. Lefer
B. Rappenglueck
(UH)
Wind Direction

Daytime: higher frequency of E directions

9:00 am – 9:00 pm (LT)

9:00 pm – 9:00 am (LT)

PIs:
B. Lefer
B. Rappenglueck
(UH)
Wind Direction

Daytime: higher frequency of E directions
Nighttime: SW (and NE) wind directions present
High $O_3$ values associated with E flow conditions
Daytime $O_3$ vs Wind Direction ($WS > 4 \text{ m/s}$)

Even under higher wind speed conditions still high $O_3$ values associated with E flow conditions.
Under higher wind speed conditions low background O$_3$ values (close to 30 ppbv) are observed at SW flow (marine) conditions in coincidence with low level O$_3$ days in O$_3$ time series.
Daytime $O_x$ vs Wind Direction (WS > 4 m/s)

Pts:
B. Lefer
B. Rappenglueck
(UH)

9:00 am – 9:00 pm (LT)

Low $O_x$ associated with W flows
Daytime $O_x$ vs Wind Direction ($WS > 4$ m/s)

Pts:
B. Lefer/
B. Rappenglueck
(UH)

9:00 am – 9:00 pm (LT)
CO, NO, NO$_2$ vs Wind Direction (Nighttime)

Plt:
B. Lefer
B. Rappenglueck
(UH)

Maximum levels usually under NNE wind flows

9:00 pm – 9:00 am (LT)
CO, NO, NO\textsubscript{2} vs Wind Direction (Nighttime)

Pts:
B. Lefer
B. Rappenglueck
(UH)

Some enhancement of NO\textsubscript{2} under SW (Parrish power plant) and SE (Texas City) flows

9:00 pm – 9:00 am (LT)
CO, NO, NO₂ vs Wind Direction (Nighttime)

PIs: B. Lefer
B. Rappenglueck (UH)

Some enhancement of NO₂ under SW (Parrish power plant) and SE (Texas City) flows

Poster: Flynn et al. : Measurements of Ozone, CO, NO, NO₂, NOₓ, and photolysis frequencies at the Moody Tower

9:00 pm – 9:00 am (LT)
NO$_y$

PI: W. Luke (NOAA)

NO$_x$ fractions:
- NO$_x$ during rush hour
- NO$_x$ during mid day (HNO$_3$?)
Rush hour: close correlation between $\text{NO}_y$ and CO
Morning rush hour CO/NO$_x$ ratio is 4.10 ± 0.029 with a background CO value of 156 ± 2 ppbv.
Traffic VOC speciation (GC/FID)

- Toluene/benzene: 3.79
- Indications for decreasing benzene levels

**Criteria:**
- Time period: 6-9 am LT
- Type of day: weekdays
- Boundary layer height: below 300 m
- Average wind direction in PBL: 270°-360°
- Std deviation of wind direction: 15°

Rush hour: high correlation between aromatic compounds, acetylene, ethylene and propylene.
Poor correlations with alkanes vs other NMHCs
Isoprene also present
### PCA Analysis (GC/FID)

**PI:** B. Rappenglueck (UH)

**Current analysis:**
C₂-C₈ VOCs (9/16-9/30)

86% of total variance explained by 5 factors

**F1:**
Industrial processes as well as evaporation.

Alkanes, several alkenes, some benzene

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*Extraction Method: Principal Component Analysis*
*Rotation Method: Varimax with Kaiser Normalization*
**PCA Analysis (GC/FID)**

Current analysis: $\text{C}_2$-$\text{C}_8$ VOCs (9/16-9/30)

86% of total variance explained by 5 factors

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F3: Industrial emissions  
\( \text{C}_4-\text{C}_5 \) alkenes

Extraction Method: Principal Component Analysis.  
Rotation Method: Varimax with Kaiser Normalization.
Current analysis: C_2-C_8 VOCs (9/16-9/30)
86% of total variance explained by 5 factors

F4:
Source yet tbd (LPG?)
i-butene, n-pentane

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Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Current analysis:
C$_2$-C$_8$ VOCs (9/16-9/30)
86% of total variance explained by 5 factors

F5:
Biogenic sources
isoprene

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Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
PCA Analysis (GC/FID)

Current analysis: C₂-C₈ VOCs (9/16-9/30)
86% of total variance explained by 5 factors

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F5: Biogenic sources
isoprene

Poster: Leuchner et al.: Measurements of VOC, PAN, Formaldehyde, and Hydrogen Peroxide at the Moody Tower Site, Houston

1-pentene: 0.61 0.58
1,2-pentene: 0.57 0.69
2,3-dimethylbutane: 0.58 0.58
2-methylpentane: 0.70 0.54
3-methylpentane: 0.68 0.57
isoprene: 0.53
benzene: 0.82
toluene: 0.77
ethylbenzene: 0.84
p,p'-xylene: 0.57
m-xylene: 0.87
o-xylene: 0.82
1,3,5-trimethylbenzene: 0.82

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
More than 20 VOCs.

Measurement periods:
08/17-09/13
10/01-10/15

Time series of alkenes, aromatics, and OVOCs.
More than 20 VOCs.
Measurement periods:
08/17-09/13
10/01-10/15

Time series of alkenes, aromatics, and OVOCs.
High values of propene, butenes, and OVOCs in the morning.
Unlike alkenes, aromatic VOCs were more correlated with the traffic conditions (e.g. peak time concurred with the morning rush hour).

More than 20 VOCs.

Here:
Hourly averaged aromatic VOCs measured from 08/17-09/01.
Unlike alkenes, aromatic VOCs were more correlated with the traffic conditions (e.g., peak time concurred with the morning rush hour).

More than 20 VOCs.

Here:
Hourly averaged aromatic VOCs measured from 08/17-09/01.

Poster:
Zheng and Zhang: VOCs and HNO₃ Measurements at the Moody Tower
Formaldehyde, PANs

Daytime: Secondary formaldehyde coincides with PAN and PPN
Formaldehyde, PANs, $H_2O_2$

Daytime: Secondary formaldehyde coincides with PAN and PPN. $H_2O_2$ peaks in the late afternoon/early evening.

Formaldehyde max.: 23.4 ppbv
Occasionally, events of elevated formaldehyde levels observed during nighttimes.
Indications for primary formaldehyde emissions? Indications for formaldehyde production through reaction of O₃ with alkenes? Indications for turbulent mixing?
Formaldehyde vs Wind Direction

Pts:
B. Rappenglueck
(UH)

09/15-09/30/06

6:00 am – 8:00 pm (LT)

Daytime:
higher HCHO values associated with E directions (Ship Channel)
Formaldehyde vs Wind Direction

Pts: B. Rappenglueck (UH)

09/15-09/30/06

6:00 am – 8:00 pm (LT)

Daytime: also some elevated values associated with SW winds (Parrish power plant?)
Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck
(UH)

09/15-09/30/06

6:00 am – 8:00 pm (LT)

Daytime: Mostly secondary HCHO

08/13-10/02/06

9:00 am – 9:00 pm (LT)

Daytime: Mostly secondary HCHO
Formaldehyde vs Wind Direction

PIs:
B. Rappenglueck (UH)

09/15-09/30/06

8:00 pm – 6:00 am (LT)
Formaldehyde vs Wind Direction

PIs:
B. Rappe
B. Rappenglueck
(UH)

09/15-09/30/06

8:00 pm – 6:00 am (LT)

Nighttime: higher HCHO values associated with NE directions, sometimes SW winds.
Formaldehyde vs Wind Direction

Pts: B. Rappenglueck (UH)

09/15-09/30/06

8:00 pm – 6:00 am (LT)

Nighttime: Secondary/primary (?) HCHO associated with NE-winds and SW winds?

08/13-10/02/06

9:00 pm – 9:00 am (LT)
Formaldehyde vs Wind Direction

PIs: B. Rappenglueck (UH)

09/15-09/30/06

- 8:00 pm – 6:00 am (LT)

Nighttime: Secondary/primary (?) HCHO associated with NE-winds and SW winds?

08/13-10/02/06

- 9:00 pm – 9:00 am (LT)

Nighttime NO₂
Event on September 29, 2006

PI:
B. Rappenglueck
(UH)
Event on September 29, 2006

PI: B. Rappenglueck (UH)
Event on September 29, 2006

PI: B. Rappenglueck (UH)
Event on September 29, 2006

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Event on September 29, 2006

PI: B. Rappenglueck (UH)
Event on September 29, 2006

Pl: B. Rappenglueck (UH)
Occasionally, elevated formaldehyde levels coincide with SO$_2$ and PANs (less correlated with CO, NO$_x$, O$_3$)
Occasionally, elevated formaldehyde levels coincide with SO$_2$ and PANs (less correlated with CO, NO$_x$, O$_3$)
Formaldehyde comparison (in-situ)

Comparison between interband cascade (IC) laser system (absorption at 3.5 μm) [Rice] and the Hantzsch-based instrumentation [UH].
Typical diurnal variations of OH and HO$_2$ were observed. OH: mid-day peak mixing ratios varied from 0.5 to 1.0 pptv. HO$_2$: mid-day peak mixing ratios varied from 40 to 100 pptv.
On average, both OH and HO$_2$ are under-predicted, day and night, which may indicate missing OH sources and/or incomplete chemistry in the model.
**HO\textsubscript{x} Budget**

**P(HO\textsubscript{x}):**
- **dominant:** \(O(\text{^3D}) + H\textsubscript{2}O\) during daytime
- \(O_3 + \text{alkene}\) reactions at night
- **others:** photolysis of HONO, HNO\textsubscript{3}, peroxides, and glyoxal

**L(HO\textsubscript{x}):**
- **dominant:** OH+NO\textsubscript{2}
- **others:** HO\textsubscript{2}+HO\textsubscript{2}, and HO\textsubscript{2}+RO\textsubscript{2}
OH-Reactivity

Calculated OH reactivity tends to be lower than the observed OH reactivity, because the calculations are only based on limited data: (1) NO$_x$, CO, O$_3$, (2) C$_2$-C$_6$ alkenes, (3) C$_2$-C$_6$ alkanes, (4) HCHO, (5) Acetylene
NOx is an important contributor to OH loss. Unknown OH reactivity is about 7-8 s\(^{-1}\) all day along.
The unknown is the difference between the measurements and calculations using currently available data. Aromatics and large carbonyls are not included in the calculations yet and should be in the unknown.
The unknown is the difference between the measurements and calculations using currently available data. Aromatics and large carbonyls are not included in the calculations yet and should be in the unknown.
HNO$_3$ with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27

Moody Tower Time Series of HNO$_3$
HNO$_3$ with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27

Daytime HNO$_3$ followed the solar cycle and was consistent with its role in the photochemical processes. The peak value was less than 1.5 ppbv, which implied that the O$_3$ production might be NO$_x$ limited.
HNO$_3$ with ID-CIMS.

Measurement periods:
08/20-09/07
09/24-09/27

Small peak at 2:30 AM, when no photochemistry could occur.

Two possible explanations:
(i) HNO$_3$ formed locally through heterogeneous reactions and
(ii) returning of aged air masses from the ocean.
**HNO₃**

**Measurement periods:**
- 08/20-09/07
- 09/24-09/27

**Poster:**
Zheng and Zhang: VOCs and HNO₃ Measurements at the Moody Tower

Small peak at 2:30 AM, when no photochemistry could occur.
Two possible explanations:
(i) HNO₃ formed locally through heterogeneous reactions and
(ii) returning of aged air masses from the ocean.
HNO₃, HONO

HNO₃ mixing ratio closely follows O₃ trend.

PI:
J. Dibb
(U New Hampshire)
HNO$_3$, HONO

HNO$_3$ lower at night, but still appreciable, suggesting significant production via NO$_3$ and N$_2$O$_5$. 

PI: J. Dibb
(U New Hampshire)
HNO$_3$, HONO

HONO mixing ratios of several hundred ppt throughout the day!
HONO shows higher values near the ground, reaching mixing ratios of up to 2 ppb.
**DOAS: HONO, NO$_3$**

**PI: Stutz (UCLA)**

NO$_3$ mixing ratios of up to 60 ppt during some nights. Vertical gradients less pronounced than expected.

HONO shows higher values near the ground, reaching mixing ratios of up to 2 ppb.
HCHO shows higher values near the ground during most nights.
HCHO shows higher values near the ground during most nights. Vertical gradients of HCHO mixing ratios during certain periods.
DOAS: HCHO, SO$_2$

HCHO shows higher values near the ground during most nights. Vertical gradients of HCHO mixing ratios during certain periods.

During several occasions plumes of SO$_2$. 

PI: Stutz (UCLA)
During the SO$_2$ plume at 9/3/06 4:00, a reversal of the HCHO profile, i.e. higher HCHO aloft, was observed. HCHO plumes correlated with SO$_2$ plumes were also observed during other times (not shown).
During the SO$_2$ plume at 9/3/06 4:00, a reversal of the HCHO profile, i.e. higher HCHO aloft, was observed. HCHO plumes correlated with SO$_2$ plumes were also observed during other times (not shown).

Poster: Stutz et al.: Vertical Profiles of O$_3$, NO$_2$, SO$_2$, HCHO, HONO, and NO$_3$ in Houston
gaseous elemental mercury in the typical urban range of 1.5 to 5.0 ng m⁻³.

Reactive gaseous mercury varied from 0.0 to ~60 pg m⁻³ with typical afternoon peaks (~3pm).
The air was extremely clean (with respect to all mercury species) on 8/26-28 and again 9/15-18. Particulate-bound mercury levels were extremely high during the early morning hours of 8/31 (not shown).

Gaseous elemental mercury in the typical urban range of 1.5 to 5.0 ng m$^{-3}$.

Reactive gaseous mercury varied from 0.0 to ~60 pg m$^{-3}$ with typical afternoon peaks (~3pm).
Particle Size Distribution

Particle counts dominated by submicron particles

Also significant numbers of large particles (≥10 µm)
Particle Growth

Particles formed through nucleation events or directly emitted were observed to grow over a time scale of a few hours.
bimodal hygroscopic growth factor distributions:
- less hygroscopic mode believed to be primarily comprised of primary organic and soot particles
- a more hygroscopic mode contains sulfate particles.
bimodal hygroscopic growth factor distributions:
- less hygroscopic mode believed to be primarily comprised of primary organic and soot particles
- a more hygroscopic mode contains sulfate particles.
Single Particle Hygroscopicity Measurements

PI:
S. Brooks
(Texas A&M)

Single particle hygroscopicity measurements conducted on time resolved impactor samples using an Environmental Scanning Electron Microscope.

Water uptake by single particles
# of experiment: 15
Dry Size Range 3.1 micron - 16 micron diameter

Relative Humidity, %

Hygroscopic Growth Factor, D/D₀
Single Particle Hygroscopicity Measurements

Single particle hygroscopicity measurements conducted on time resolved impactor samples using an Environmental Scanning Electron Microscope.

Particles were reasonably hygroscopic, taking up significant amounts of water at relative humidities above 70% and increasing to ~180% of their original size at RHs above 90%.
Particle Composition

PI:
R. Griffin  (U New Hampshire)

Mass concentrations dominated by organic material and sulfate aerosol. Organic aerosol concentrations show a large increase in the morning and again late in the day. Total number concentrations follow organic aerosol species.
Large spike in nitrate aerosol that appears to be associated with organic aerosol material. Increase corresponds to a rapid decrease in gas-phase concentrations of nitric acid.
Water soluble gases and aerosols

Small peak in the water soluble gases at 5 am. Wind direction indicates Ship Channel as possible source region. However, also rush hour traffic impact.
Water soluble gases and aerosols

Water soluble gas and aerosol concentrations increase rapidly as the sun rises (gas peak of 40 μg/m³ at noon is very high compared to other locations)

PI:
J. Dibb
(U New Hampshire)
Pattern in the concentration of water soluble organics compares well with AMS data. Midday peak appears to be due to oxidation of primary organic emissions, which increases the solubility of the organic compounds.
Time series of the water-soluble fraction of PM2.5 organic carbon.
Two main sources for WSOC:
(i) biomass burning emissions
(ii) secondary organic aerosol formation.
Aerosol optical properties

No clear indication of a single dominant source of PM in Houston.
Aerosol optical properties

PI:
D. Atkinson
(Portland State U)

However, indications that much of PM, and primary and secondary chemical contaminants originate in the ship channel area. Episodically, emissions from local industries as well as longer range transport of PM often contributed dramatically to the total light.
Aerosol optical properties

PI: D. Atkinson
(Portland State U)

Optical Property Day Averages 08-14-06 to 09-27-06

- Particle extinction coefficient
- Particle absorption coefficient
- Particle scattering coefficient

Mm\(^{-1}\)

Ext & Scat Abs

Monday Tuesday Wednesday Thursday Friday Saturday Sunday

Day of the Week
**Aerosol optical properties**

**PI:**
D. Atkinson
(Portland State U)

**Weekly pattern of aerosol optical extinction (and scattering) shows a Monday-Wednesday “weekend” signal.**
Sporting events and other recreational activities responsible?
The low levels of PM on Monday, Tuesday, and Wednesday are not as easy to rationalize.
Aerosol optical properties

Poster:
Wright et al.: Ambient Observations of Aerosol Optical Properties during TexAQS-II using Cavity Ring-Down

Sporting events and other recreational activities responsible? The low levels of PM on Monday, Tuesday, and Wednesday are not as easy to rationalize.
Photolysis frequencies currently calculated

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Rate Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[\text{O}_3 + \text{hv} \rightarrow \text{O}_2 + \text{O}(1D)]$</td>
<td>$[\text{CHOCHO} + \text{hv} \rightarrow \text{HCO} + \text{HCO}]$</td>
</tr>
<tr>
<td>$[\text{NO}_2 + \text{hv} \rightarrow \text{NO} + \text{O}(3P)]$</td>
<td>$[\text{CH}_3\text{COCHO} + \text{hv} \rightarrow \text{products}]$</td>
</tr>
<tr>
<td>$[\text{N}_2\text{O}_5 + \text{hv} \rightarrow \text{NO}_3 + \text{NO} + \text{O}(3P)]$</td>
<td>$[\text{CH}_3\text{COCH}_3 + \text{hv} \rightarrow \text{products}]$</td>
</tr>
<tr>
<td>$[\text{N}_2\text{O}_5 + \text{hv} \rightarrow \text{NO}_3 + \text{NO}_2]$</td>
<td>$[\text{CH}_3\text{OOH} + \text{hv} \rightarrow \text{CH}_3\text{O} + \text{OH}]$</td>
</tr>
<tr>
<td>$[\text{HO}_2\text{O} + \text{hv} \rightarrow \text{2OH}]$</td>
<td>$[\text{CH}_3\text{ONO}_2 + \text{hv} \rightarrow \text{CH}_3\text{O} + \text{NO}_2]$</td>
</tr>
<tr>
<td>$[\text{HONO} + \text{hv} \rightarrow \text{OH} + \text{NO}]$</td>
<td>$[\text{PAN} + \text{hv} \rightarrow \text{products}]$</td>
</tr>
<tr>
<td>$[\text{HNO}_3 + \text{hv} \rightarrow \text{OH} + \text{NO}_2]$</td>
<td>$[\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{hv} \rightarrow \text{C}_3\text{H}_7 + \text{HCO}]$</td>
</tr>
<tr>
<td>$[\text{HCHO} + \text{hv} \rightarrow \text{H} + \text{HCO}]$</td>
<td>$[\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{hv} \rightarrow \text{C}_2\text{H}_4 + \text{CH}_2\text{CHOH}]$</td>
</tr>
<tr>
<td>$[\text{HCHO} + \text{hv} \rightarrow \text{H}_2 + \text{CO}]$</td>
<td>$[\text{CH}_3\text{COCH}_2\text{CH}_3 + \text{hv} \rightarrow \text{products}]$</td>
</tr>
<tr>
<td>$[\text{CH}_2\text{CHO} + \text{hv} \rightarrow \text{CH}_3 + \text{HCO}]$</td>
<td>$[\text{HO}_2\text{NO}_2 + \text{hv} \rightarrow \text{HO}_2 + \text{NO}_2]$</td>
</tr>
<tr>
<td>$[\text{CH}_3\text{CHO} + \text{hv} \rightarrow \text{CH}_4 + \text{CO}]$</td>
<td>$[\text{HO}_2\text{NO}_2 + \text{hv} \rightarrow \text{OH} + \text{NO}_3]$</td>
</tr>
<tr>
<td>$[\text{C}_2\text{H}_5\text{CHO} + \text{hv} \rightarrow \text{C}_2\text{H}_4 + \text{HCO}]$</td>
<td>$[\text{CH}_3\text{CH}_2\text{ONO}_2 + \text{hv} \rightarrow \text{products}]$</td>
</tr>
<tr>
<td>$[\text{CHOCHO} + \text{hv} \rightarrow \text{products}]$</td>
<td></td>
</tr>
</tbody>
</table>
Radiation Measurements

PI:
B. Lefer (UH)

\[ j(\text{NO}_2) \text{ and } j(\text{O}_1\text{D}) \]: Clear sky conditions and sky camera photo
Radiation Measurements

PI: B. Lefer (UH)

j(NO₂) and j(O1D): At noon sky is “milkier” than under clear sky conditions
Significant changes in photolysis frequencies due to clouds and aerosols observed during the TRAMP campaign, e.g. $j[O_3 \rightarrow O(1D) + O_2]$.
Significant changes in photolysis frequencies due to clouds and aerosols observed during the TRAMP campaign, e.g. $j[O_3 \rightarrow O(1D) + O_2]$
Boundary Layer Studies

PI: C. Flynn (UH)

Micropulse LIDAR used to determine planetary boundary layer based on aerosol backscatter

Black dots represent a preliminary implementation of a wavelet covariance filter algorithm for detection of the PBL.
**Moody Tower Measurements**

- **Some preliminary Results:**
  - Large differences between marine and continental background conditions
  - Complex VOC-emissions
    - Application of CMAQ with explicit VOC-Chemistry (Aromatics, Alkenes)
  - Highly reactive VOC Chemistry not only during daytime, also nighttime chemistry important:
    - Nighttime OH-formation (e.g. VOC-reactions with NO$_3$; NO$_3$ between 60-100 ppt)
    - Nighttime formaldehyde formation (O$_3$ reaction with alkenes?)
  - High mixing ratios of formaldehyde and HONO lead to enhanced production of radicals and subsequent oxidative VOC-degradation and supposedly enhanced formation of SOA
  - Significant particle growth, partly favored through high relative humidity.
  - Significant fraction of organic aerosol.
  - Enhanced fraction of water soluble organics, supposedly due to oxidation of primary organic emissions.
Moody Tower Measurements

Complete Data Analysis not yet completed...
Moody Tower Measurements

Good News:

Comprehensive Final Data Analysis
this summer!
(supported by TCEQ and HARC)

Moody Tower Data Analysis Workshop
(tentative dates: July 16-18 at UH)
Thank you!